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Construction Technique for Optimized Data Transmission Over Wireless Radio Network

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***Abstract*—Cognitive Radio is a radio for wireless communications in which either a network or a wireless node changes its transmission or reception parameters based on the interaction with the environment to communicate efficiently without interfering with licensed users." This changing of parameters is based on the active monitoring of external and internal radio environment such as radio frequency spectrum, user behavior trends and network state. Simply, the idea behind the cognitive radio paradigm is the utilization of the idle frequency bands allocated to primary users or licensed users by the secondary users or unlicensed users without any interference to primary users' communications. For the spectrum sensing in Cognitive Radio Networks we are choosing the time-varying nature of wireless channels, such as fading, multipath makes it difficult for wireless system designers to satisfy the ever-increasing expectations of mobile users in terms of data rate and Quality of Service (QoS). The limited radio spectrum and limitation on the processing power availability in the portable handheld unit of mobile user are the other important constraints in designing wireless systems.**

Keywords-Spectrum sensing, Quality of Service (QoS), Cognitive Radio Networks(CRN), Fading Channels, multiple-input and multiple-output(MIMO).

I. INTRODUCTION

Wireless communications has made a tremendous impact on the lifestyle of a human being. It is very difficult to survive without wireless in some form or the other. As compared to fixed wireless systems, today's wireless networks provide high speed mobility (mobile users in fast vehicles) for voice as well as data traffic. The time-varying nature of wireless channels, such as fading, multipath makes it difficult for wireless system designers to satisfy the ever-increasing expectations of mobile users in terms of data rate and Quality of Service (QoS). The limited radio spectrum and limitation on the processing power availability in the portable handheld unit of mobile user are the other important constraints in designing wireless systems. Continuous exponential growth of Internet, Cellular Mobile and Multimedia Services in the near past has been the driving forces for the increased demand of data rates in Communication Networks. The integration of Internet and multimedia applications in wireless communications follows the quest for increased data rates and spectrally efficient signaling techniques.

3G cellular systems operating in 2 GHz band has promised data rates of at least 384 kbps for mobile and 2 Mbps for indoor applications. 4G systems are to yield about 20-40 Mbps. An IP based 4G systems which are considered to be an integration of 3G systems and wireless LAN (WLAN) systems The universal goal in all approaches towards 4G for achieving high data rates is increasing spectral efficiency using MIMO techniques. The work carried out on MIMO capacity limits shows that, capacity of MIMO channels increase approximately linearly with increased number of antennas

II. COGNITIVE RADIO NETWORKS

Cognitive Radio is a radio for wireless communications in which either a network or a wireless node changes its transmission or reception parameters based on the interaction with the environment to communicate efficiently without interfering with licensed users." This changing of parameters is based on the active monitoring of external and internal radio environment such as radio frequency spectrum, user behavior trends and network state.

Simply, the idea behind the cognitive radio paradigm is the utilization of the idle frequency bands allocated to primary users or licensed users by the secondary users or unlicensed users without any interference to primary users' communications. If we scan the portions of radio spectrum, we would find that some frequency bands are largely unoccupied most of the time while some other frequency bands are only partially occupied and the remaining frequency bands are heavily used (Haykin 2005),(FCC Report 2002). Hence cognitive radio aims to detect those idle bands and allocate the secondary users to those. It is assumed that cognitive radio senses the environment in a period of time and if primary user needs to start communicating, secondary users are moved to another idle band. In doing so the cognitive radios change the power level so that to minimize the interference that may caused due to the secondary users. Thus, we see that knowing the availability of the idle spectrum band is not enough to decide the usage of unused spectrum bands. Many factors like

frequency selection, modulation schemes and power level should be considered to capture the variation in radio environment so as to avoid possible interference to other users. The Federal Communication Commission (FCC) has identified in (FCC Report 2002) the following features that cognitive radios can incorporate to enable a more efficient and flexible usage of the spectrum.

III. CLASSIFICATION OF FADING CHANNELS

If in a communication channel the details of the medium are not known then the propagation is considered to be in free space (A propagating medium is said to be a free space if the communication channel is free of objects that absorb or reflect radio energy). Fading occurs, as a channel cannot remain free of noise and the effects of the fading on the signal transmitted is left to be seen in the coming portions, A signal transmitted from a transmitting antenna reaches the receiving antenna by a multiply reflected component and/or a Line-of-Sight component. Depending on these two components fading is classified into two major cases namely:

- Large scale fading and
- Small scale fading.

A. LARGE SCALE FADING

Large Scale Fading occurs when signal passes over large areas such as buildings, hills and forest and as a result suffer a path loss or attenuation in its power. The relation that gives the path loss for any channel is

$$L_s(d) = \left[4\pi d / \lambda\right]^2$$

It is termed as 'shadow' effect where in the receiver lies in the shadows of these obstacles.

The channel experiences loss in signal power during propagation in three ways.

- Reflection
- Diffraction
- Scattering

The effect of the above three phenomena on large scale fading is the path loss. The path loss in a channel involving large-scale fading is given by the relation

$$L_p(d)(dB) = L_s(d_0)(dB) + n10\log_{10}(d/d_0) + X_a(dB)$$

Where,

$L_s(d_0)$ = Path Loss of the signal at a constant distance.

X_a = Zero Mean Gaussian random variable in decibels.'

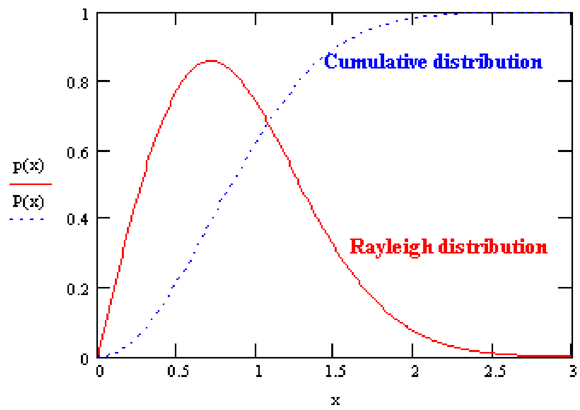
d_0 = distance between the transmitter and receiver.

The value of n depends on the type of environment present. For a free space n=2, presence of strong guided waves n<2 and n>2 when huge obstacles are present. Thus the factors that affect the large scale fading are d_0, n, X_a.

B. SMALL SCALE FADING

Small scale fading is also called Rayleigh fading or Scintillation. Small scale fading causes change in the signal amplitude and phase due to multiple path reflection. If the received signal has a line-of-sight component then the fading envelope is given by Rician PDF. Rician fading represents a Rayleigh PDF, whenever the line of sight component approaches zero. It is assumed that the loss of SNR due to fading follows Rayleigh fading.The phenomenon of small scale fading is explained by

- Time spreading of pulses (Signal Dispersion).
- Time variance behavior of channel (Fading rapidity



of channel).

It is depicted that the relation between received power and the delay as a function of antenna position for a multipath channel. It can be seen that the response pattern behaves differently for different positions of the antenna.

The time spreading principle is explained in two domains namely:

- Time delay domain
- Frequency domain

Similarly the time variance of the channel is explained in two domains namely:

- Time domain
- Doppler shift domain

The former two domains define frequency selective fading and flat fading or frequency non selective fading degradation types whereas the latter defines fast and slow fading as channel degradation.

C. STATISTICAL MODELS FOR FADING CHANNELS

There are several probability distributions that can be considered in attempting to model the statistical characteristics of the fading channel.

- Rayleigh Fading
- Rician Fading

1) RAYLEIGH FADING

Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal, such as that used by wireless devices. Rayleigh fading models assume that the magnitude of a signal that has passed through such a transmission medium (also called a communications channel) will vary randomly, or fade, according to a Rayleigh distribution — the radial component of the sum of two uncorrelated Gaussian random variables. Rayleigh fading is viewed as a reasonable model for tropospheric and ionospheric

signal propagation as well as the effect of heavily built-up urban environments on radio signals. Rayleigh fading is most applicable when there is no dominant propagation along a line of sight between the transmitter and receiver. If there is a dominant line of sight, Rician fading may be more applicable.

Rayleigh fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver. The central limit theorem holds that, if there is sufficiently much scatter, the channel impulse response will be well-modeled as a Gaussian process irrespective of the distribution of the individual components. If there is no dominant component to the scatter, then such a process will have zero mean and phase evenly distributed between 0 and 2π radians. The envelope of the channel response will therefore be Rayleigh distributed.

The PDF of Rayleigh channel is

$$P_R(r) = 2r/\Omega \exp(-r^2/\Omega)$$

Where $\Omega = E(R^2)$

It is observed that the Rayleigh distribution is characterized by the single parameter E (R^2). Another statistical model for the envelope of the channel response is the Nakagami-m distribution given by the pdf

$$P_R(r) = 2/\Gamma(m) \ (m/\Omega)^m \ r^{2m-1} \exp(-mr^2/\Omega)$$

In contrast the Rayleigh distribution, which has a single parameter that can be used to match the fading channel statistics, the Nakagami-m is a two -parameter distribution. Namely involving the parameter m and second moment Ω= E (R^2) as a consequence, this distribution provides more flexibility and accuracy in matching the observed signal statistics. The Nakagami-m distribution can be used to model fading channel conditions that are either more or less severe than the Rayleigh distribution, and it includes the Rayleigh distribution as a special case (m=1).

The requirement that there be many scatterers present means that Rayleigh fading can be a useful model in heavily built-up city centre where there is no line of sight between the transmitter and receiver and many buildings and other objects attenuate, reflect, refract and diffract the signal. In tropospheric and ionospheric signal propagation the many particles in the atmospheric layers act as scatterers and this kind of environment may also approximate Rayleigh fading. If the environment is such that, in addition to the scattering, there is a strongly dominant signal seen at the receiver, usually caused by a line of sight, then the mean of the random process will no longer be zero, varying instead around the power-level of the dominant path. Such a situation may be better modeled as Rician fading.

2) RICIAN FADING

Rician fading is a stochastic model for radio propagation anomaly caused by partial cancellation of a radio signal by itself- the signal arrives at the receiver by two different paths, and at least one of the paths is changing (lengthening or shortening). Rician fading occurs when one of the paths, typically a line of sight signal, is much stronger than the others. In Rician fading, the amplitude gain is characterized by a Rician distribution.

Rayleigh fading is the specialized model for stochastic fading when there is no line of sight signal, and is sometimes considered as a special case of the more generalized concept of Rician fading. In Rayleigh fading, the amplitude gain is characterized by a Rayleigh distribution. In order to obtain the probability density of the signal amplitude it is observed that the random processes I(t) and Q(t) at one particular instant t_0 . If the number of scattered waves is sufficiently large, and are identically and independently distributed (i.i.d) the central limit theorem says that I (t_0) and Q (t_0 are Gaussian, but, due to the deterministic dominant term, no longer zero mean. Transformation of variables shows that the amplitude and the phase have the joint PDF. Here is the local-mean scattered power and is the power of the dominant component. The PDF of the amplitude is found from the integral.

$$P_R(r) = r/\sigma^2 \exp[(-r^2 + c_a^2)/2\sigma^2] I_a(c_a r/\sigma^2)$$

Where, I_a - is the modified Bessel function of the first kind and zero order and is given by

a)

$$I_a = 1/2\pi \int_{-\pi}^{\pi} \exp(x\cos(\theta))d\theta$$

Rician Factor

The Rician K-factor is defined as the ratio of signal power in dominant component to the (local-mean) scattered power. Thus $K = c_a^2/2\sigma^2$. The PDF of the Rician channel in terms of Rician factor is given by

$$P_R(r) = \frac{2(1+K)r}{\Omega}\exp(-K)\exp\left(-\frac{(1+K)r^2}{\Omega}\right)I_0\left(2r\sqrt{\frac{K(1+K)}{\Omega}}\right)$$

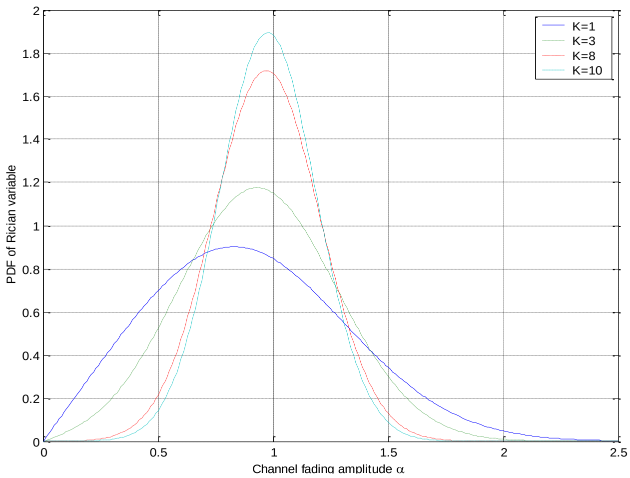


Figure 1. PDF of the Rician channel

3) Nakagami Fading

Unfortunately, mobile radio links are subject to severe multipath fading due to the combination of randomly delayed, reflected, scattered, and diffracted signal components. Fading leads to serious degradation in the link carrier to noise ratio (CNR), leading to higher bit error rate (BER). Rayleigh and Rician fading models have been widely used to simulate small scale fading environments.

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IV. MIMO

In radio, multiple-input and multiple-output, or MIMO (pronounced *mee-moh* or *my-moh*), is the use of multiple antennas at both the transmitter and receiver to improve communication performance. It is one of several forms of smart antenna technology.MIMO technology has attracted attention in wireless communications, since it offers 5significant increases in data throughput and link range without additional bandwidth or transmit power. It achieves this by higher spectral efficiency (more bits per second per hertz of bandwidth) and link reliability or diversity (reduced fading). Because of these properties, MIMO is a current theme of international wireless research.

A. *Functions of MIMO*

MIMO can be sub-divided into three main categories, precoding, spatial multiplexing or SM, and diversity coding.

Precoding is multi-layer beam forming in a narrow sense or all spatial processing at the transmitter in a wide-sense. In (single-layer) beam forming, the same signal is emitted from each of the transmit antennas with appropriate phase (and sometimes gain) weighting such that the signal power is maximized at the receiver input. The benefits of beam forming are to increase the signal gain from constructive combining and to reduce the multipath fading effect. In the absence of scattering, beam forming results in a well defined directional pattern, but in typical cellular conventional beams are not a good analogy. When the receiver has multiple antennas, the transmit beam forming cannot simultaneously maximize the signal level at all of the receive antenna and precoding is used. Precoding requires knowledge of the channel state information (CSI) at the transmitter.

SPATIAL MULTIPLEXING requires MIMO antenna configuration. In spatial multiplexing, a high rate signal is split into multiple lower rate streams and each stream is transmitted from a different transmit antenna in the same frequency channel. If these signals arrive at the receiver antenna array with sufficiently different spatial signatures, the receiver can separate these streams, creating parallel channels for free. Spatial multiplexing is a very powerful technique for increasing channel capacity at higher Signal to Noise Ratio (SNR). The maximum number of spatial streams is limited by the lesser in the number of antennas at the transmitter or receiver. Spatial multiplexing can be used with or without transmit channel knowledge.

DIVERSITY CODING techniques are used when there is no channel knowledge at the transmitter. In diversity methods a single stream (unlike multiple streams in spatial multiplexing) is transmitted, but the signal is coded using techniques called space-time coding. The signal is emitted from each of the transmit antennas using certain principles of full or near orthogonal coding. Diversity exploits the independent fading in the multiple antenna links to enhance signal diversity. Because there is no channel knowledge, there is no beam forming or array gain from diversity coding.

Spatial multiplexing can also be combined with precoding when the channel is known at the transmitter or combined with diversity coding when decoding reliability is in trade-off.

B. *SYSTEM AND CHANNEL MODEL*

Consider a point-to-point MIMO system with n_t transmit and n_r receive antennas. The block diagram is given in Fig.2.

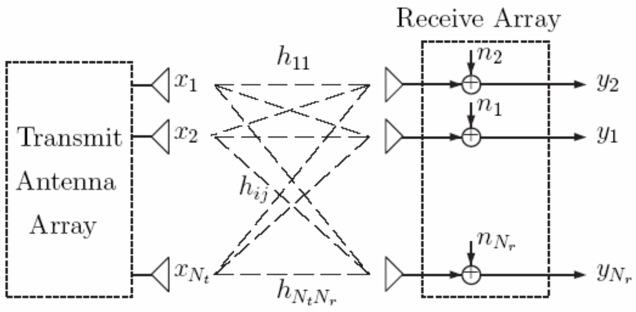

Figure 2. MIMO channel model.

et $h_{i,j}$ be a complex number corresponding to the channel gain between transmit antenna *j* and receive antenna *i*. If at certain time instant the complex signals $\{s_1, s_2, ...s_n\}$ are transmitted via n_t transmit antennas, the received signal at antenna *i* can be expressed as:

$$y_i = \sum_{j=1}^{n_i} h_{i,j} s_j + n_i$$

where n_i is a noise term. Combining all receive signals in a vector y, the above equation can be easily expressed in matrix form

$$\mathbf{y} = \mathbf{Hs} + \mathbf{n}$$

y is the n_r x 1 receive symbol vector, **H** is the n_r x n_t MIMO channel transfer matrix,

$$\mathbf{H} = \begin{bmatrix} h_{1,1} & \cdots & h_{1,n_t} \\ \cdots & \cdots & \cdots \\ h_{n_r,1} & \cdots & h_{n_r,n_t} \end{bmatrix}$$

s is the n_t x 1 transmit symbol vector and n is the n_r x 1 additive noise vector. The system model implicitly assumes a flat fading MIMO channel, i.e., channel coefficients are constant during the transmission of several symbols. Flat fading, or frequency non-selective fading, applies bye definition to systems where the bandwidth of the transmitted signal is much smaller than the coherence bandwidth of the channel. All the frequency components of the transmitted signal undergo the same attenuation and phase shift propagation through the channel. The transmit symbols are assumed as uncorrelated, that means

$$E\{ss^H\} = P_s I$$

where P_s denotes the mean signal power of the used modulation format at each transmit antenna. This implies that only modulation formats with the same mean power on all transmit antennas are considered.

C. CHANNEL CAPACITY

Information-theoretic studies of wireless channels have been performed extensively. It has been show that the increase of MIMO capacity is huge compared to the capacity of a SISO system. One of the most important fields in the research area of MIMO systems is how to exploit this potential increase in channel capacity in an efficient way. There are a lot of approaches, which can mainly be subdivided into space-time coded and uncoded transmission systems.The maximum error-free data rate that a channel can support is called the channel capacity. The channel capacity for SISO AWGN channels was derived by Claude Shannon. In contrast to AWGN channels, multiple antenna channels combat fading and cover a spatial dimension.

The capacity of a deterministic SISO channel with an input-output relation $r = Hs + n$ is given by

$$C = \log_2(1+\rho|H|^2) \text{ [Bits/channel use]}$$

where the normalized channel power transfer characteristic is $|H|^2$. The average SNR at each receiver branch independent of n_t is $\rho = P/\sigma_n^2$ and P is the average power at the output of each receive antennas.

The channel capacity of a deterministic MIMO channel is given by

$$C = \log_2\left[\det\left(I_{n_r} + \frac{\rho}{n_t}HH^H\right)\right] \text{ [bits/channel]},$$

and for random MIMO channels, the mean channel capacity, also called the ergodic capacity, is given by

$$C = \xi_H\left\{\log_2\left[\det\left(I_{n_r} + \frac{\rho}{n_t}HH^H\right)\right]\right\}$$

where ξ_H denotes expectation with respect to **H**. The ergodic capacity grows with the number *n* of antennas (under the assumption $n_t = n_r = n$), which results in a significant capacity gain of MIMO fading channels compared to a wireless SISO transmission.

C is Channel Capacity, ρ is SNR, σ_n^2 is variance of AWGN.

D. Application of MIMO

Spatial multiplexing techniques makes the receivers very complex, and therefore it is typically combined with Orthogonal Frequency Division Multiplexing (OFDM) or with Orthogonal Frequency Division Multiple Access (OFDMA) modulation, where the problems created by multi-path channel are handled efficiently. The IEEE 802.16e standard incorporates MIMO-OFDMA. The IEEE 802.11n standard, which is expected to be finalized soon, recommends MIMO-OFDM.

MIMO is also planned to be used in Mobile radio telephone standards such as recent 3GPP and 3GPP2 standards. In 3GPP, High-Speed Packet Access plus (HSPA+) and Long Term Evolution (LTE) standards take MIMO into account. Moreover, to fully support cellular environments MIMO research consortia including IST-MASCOT propose to develop advanced MIMO techniques, i.e., multi-user MIMO (MU-MIMO).

V. SPECTRUM SENSING METHODS

The terms "Cognitive Radio" and "Dynamic Spectrum Access" arise from recent technological and regulatory trends in the area of wireless communication. A "radio" is any device that can receive and transmit radio frequency signals, everything from cell phones to WiFi-enabled computers. Recent advances in radio technology now allow radios to be "agile" in the sense that they can reconfigure themselves to dynamically receive and transmit on a wide variety of channels using a variety of communication modes. A cognitive radio is a radio that has some ability to represent and reason about goals, policies, features of the external world, aspects of its internal state, etc., that relate to radio communication. For example a cognitive cell-phone, upon boarding an aircraft, could use its policy knowledge, context awareness, and reasoning capability to automatically disable its radio frequency functions.

Organizations that regulate radio frequency spectrum access are beginning to take account of these developments. For example, crowding on certain areas of the spectrum, has led regulators to propose and, in some regions, adopt, policies under which portions of licensed or regulated spectrum - spectrum that has been pre-allocated to certain users or uses - can be dynamically accessed by secondary users when not in use by the licensed users. For example, in some low population areas of the US, reuse of idle analog TV spectrum for wireless internet access seems to be a good way of providing service to areas that are currently under-served. makers and designers/implementers will need to share a common understanding of evolving radio technologies and cognitive radios themselves will need to be able to communicate their status, priorities and goals with each other in an unambiguous manner. In order to investigate and determine the knowledge representation and reasoning technologies and capabilities required to achieve this vision.

(5.5)

A. PROBLEM FORMULATION

we first present the general model for channel sensing, and then review the energy detection scheme and analyze the relation between the probability of detection, probability of miss detection and probability of false alarm.

B. GENERAL MODEL

The goal of spectrum sensing is to determine if a licensed band is not currently being used by its primary owner. This in turn may be formulated as a binary hypothesis testing problem

Two conditions are possible under hypothesis test

1. When the primary user is not active, the received signal at the secondary user can be represented as

$$y(n) = u(n)$$

Where $y(n)$ is the signal received by the secondary user and $u(n)$ is noise.

2. When the primary user is active, the received signal is given by

$$y(n) = h(n)s(n) + u(n)$$

Where $s(n)$ the signal is transmitted by the primary users and received by secondary users over a channel $h(n)$. When the channel is non-fading, $h(n)$ is constant. It is assumed that noise samples $u(n)$ are independently and identically distributed

(i.i.d.) with zero mean and variance $E\left[\left|u(n)\right|^2\right]=\sigma_u^2$ based on the received signal

C. *Theory of Hypothesis Testing*

The goal of spectrum sensing is to make a decision, i.e. to choose between H_0 and H_1, based on the received signal [5].The probability density function (PDF) under each hypothesis is shown in Fig3 and Fig.4, where the threshold value for each hypothesis is denoted as.

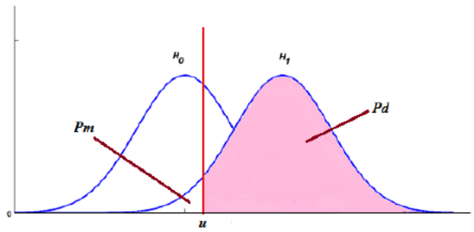

Figure 3. Theory of hypothesis testing; probability of detection and probability of missed detection

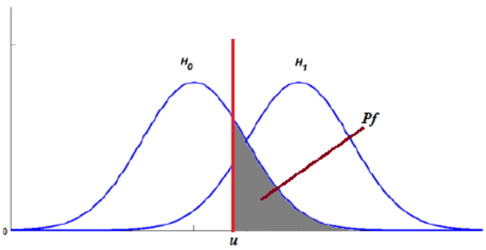

Figure 4. Theory of hypothesis testing; probability of false alarm

Generally, two probabilities are of interest for indicating the performance of a sensing algorithm.

(1) Probability of detection P_d, defines the probability of the sensing algorithm having detected the presence of the primary signal at the hypothesis H_1 .Thus, in Fig. 3, under the hypothesis, the PDFs bigger than the threshold value u is defined as the detection probability. The PDFs smaller than the threshold u is defined as probability of missed detection, P_m.

(2) Probability of false alarm, P_f, defines at the hypothesis H_0, the probability of the sensing algorithm claiming the presence of the primary signal. That is, if we decide H_1, but is true, it is called a false alarm error. In Fig. 4, the PDFs exceeding the threshold under the hypothesis H_0 are defined as P_f.

D. *Cogntive Channel Model*

As a preliminary, we set up the model for signal detection.

Consider a time continuous signal $\chi(t)$. We wish to express the time-continuous signal in a discrete vector representation over a finite time interval. In general, the signal can be expressed by a basis expansion.

$$\chi(t)=\sum_{i=1}^{N} x_i\phi_i(t)$$

Where $\phi_i(t)$ basis functions then the signal are $\chi(t)$ can be represented by the vector $X \triangleq (x_1, x_1, \ldots\ldots x_N)^T$

Assume that y is a received vector of length N, that consists of a signal plusnoise. That is

$$y = x + w$$

First we detect whether there is a signal present or not we provide the separation between H_0 and H_1

$$\left.\begin{aligned} y=w \quad & H_0: \ \text{signal is absent} \\ y=x+w: & H_1: \ \text{signal is present} \end{aligned}\right\}$$

The optimal Neyman-Pearson test is to compare the log-likelihood ratio to threshold i.e.

$$\Lambda_e \triangleq \log\left[\frac{P\left(y/H_1\right)}{P\left(y/H_0\right)}\right] \underset{H_0}{\overset{H_1}{\gtrless}} \eta$$

This ratio depends on the distribution of the signal to be detected

Note: No cyclic prefix $N_c=0$ (energy detection) so that there is no structure in the signal that can be used then

$$T_\tau T_\tau^T = I$$

Under H_0, $y/H_0 \sim CN\left(0,\sigma^2 I\right)$

Under H_1, $y/H_1 \sim CN\left(0,\left(\sigma_n^2+\sigma_s^2\right)I\right)$

Therefore log-likelihood ratio is

$$\log\left[\frac{P\left(y/H_1\right)}{P\left(y/H_0\right)}\right] = \log\left(\frac{\frac{1}{\pi^N\left(\sigma_n^2+\sigma_s^2\right)^N}\exp\left(-\frac{\|y\|^2}{\sigma_n^2+\sigma_s^2}\right)}{\frac{1}{\pi^N\sigma_n^{2N}}\exp\left(-\frac{\|y\|^2}{\sigma_n^2}\right)}\right)$$

By removing all constraints that are independent of the received vector y, we obtain the optimal Neyman-Pearson test

$$\Lambda_e \triangleq \|y\|^2 = \sum_{i=0}^{N-1}\left|y_i\right|^2 \underset{H_0}{\overset{H_1}{\gtrless}} \eta_e$$

In this case the energy detector is also known as radiometer

E. *Local Spectrum Sensing*

The performance of a given spectrum sensing scheme is fundamentally limited by the radio propagation channel. Typically, the effects of a radio channel can be divided into three main parts: path loss, small-scale fading, and large-scale fading (shadowing). Path loss effects are incorporated in the received SNR at a cognitive radio terminal. Small-scale fading causes rapid, random variations in the signal strength at the CR receiver and is modeled by Rayleigh fading in this paper. Shadowing is the slow variation of received signal power as the cognitive radio moves in and out of the shadow of large

structures like mountains, buildings, and so forth. Shadowing is often modeled as a lognormal distributed random process that varies around a local mean given by the path loss and with the standard deviation σdB which depends on the environment.

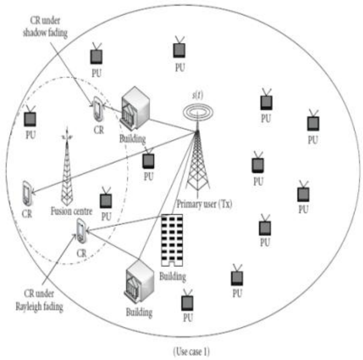

Figure 5. The considered scenario

The local spectrum sensing is accomplished by the energy detection. An energy detector is implemented at each secondary user by calculating a decision metric out of all samples and antennas used. The purpose of energy detection is to make a correct decision between two hypotheses after observing samples. The energy detection should be carried out over all logical channels defined by the CR network. Assuming that the channel is time-invariant during the sensing process, the energy detection on the given channel is performed by accumulating the energy of samples and comparing it with the predefined threshold, to decide whether signal is present or not.

VI. CONCLUSION

In the standardization process of vehicular networks, channel models are required to evaluate and select the proposed physical layer modulation and coding schemes. Analytical and simulation results are provided to support the theoretical formulations and derivations. The presented results show that spectrum sensing and access in vehicular communication can be improved by modeling the wireless environment precisely. IN a cognitive radio network (CRN), in-band spectrum sensing is essential for the protection of legacy spectrum users, with which the presence of primary users (PUs) can be detected promptly, allowing secondary users (SUs) to vacate the channels immediately. For in-band sensing, it is important to meet the detectability requirements, such as the maximum allowed latency of detection (e.g., 2 seconds in IEEE 802.22) and the probability of misdetection and false-alarm. From the presented result it is clear that a channel model composed of mixed distributions is useful for designing vehicular wireless.

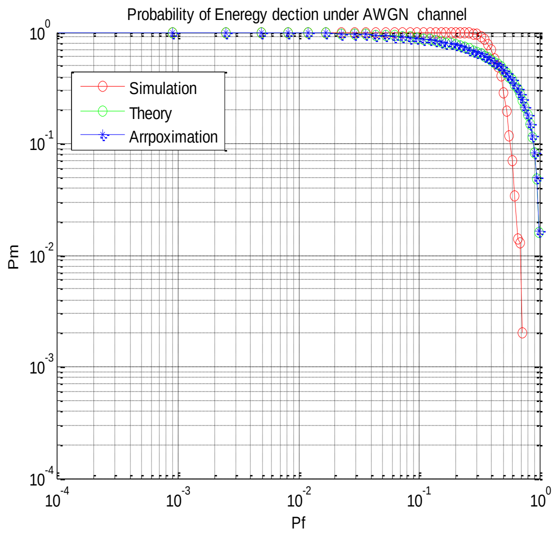

Figure 6. Perfect energy detection under AWGN channel

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